

STRATEGIC PLAN



PLANNING FOR
SUSTAINABLE DEVELOPMENT

INTRODUCTION

Energy is the fuel that drives the Nation's economy and allows the United States to enjoy a superior standard of living.

As the United States stands on the threshold of a new millennium, it faces both tremendous opportunities for continued economic growth and the challenges of providing the clean, affordable energy necessary to sustain that growth without harming the environment.

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from fossil fuels. In supplying this energy need, however, the Nation must address growing global and regional environmental concerns and energy prices. Maintaining low-cost electricity in the face of growing demand and increasing environmental pressure requires new technologies. These technologies must allow the Nation to use its indigenous resources more wisely, cleanly, and efficiently. These resources include inherently clean natural gas and the Nation's most abundant and lowest cost resource, coal; while expanding the resources base to include "opportunity" fuels and feedstocks, such as biomass and wastes for use in co-firing.

The role of the federal government will be to provide support in developing advanced fossil energy technologies that ensure continued environmental and economic benefits. The Coal & Power Systems (C&PS) programs, which include Vision 21, Central Power Systems, Distributed Generation, Fuels, Carbon Sequestration, and Advanced

Research, were developed to align with and directly support the goals and objectives of the Comprehensive National Energy Strategy. This strategy was developed by the U.S. Department of Energy (DOE) in concert with other federal agencies and major stakeholders. The C&PS programs address key domestic and global environmental concerns, while being responsive to the DOE strategies to promote secure, efficient, and comprehensive energy systems, and enhance scientific understanding.

More than 15 years ago it was recognized that, given the need to respond to increased environmental objectives, new technologies would be necessary if coal was to continue as a viable source of secure energy. In 1985, the U.S. Clean Coal Technology (CCT) Demonstration Program was initiated with the objective to demonstrate a new generation of advanced coal utilization technologies.

The projects conducted under the CCT program have generated, and are continuing to generate, an enormous amount of valuable technical, environmental, and economic performance data on commercial-scale technologies. This investment in technology forms a solid foundation for addressing growing global and regional environmental concerns while continuing to provide low-cost energy. The C&PS program builds upon the successes of the CCT program and, in turn, provides a solid foundation for a new total energy concept called Vision 21.

The Vision 21 concept allows the Nation to realize the full potential of its abundant fossil fuel resources

by maintaining and strengthening the integral role of fossil fuels in the Nation's energy mix. Vision 21 is the long-range strategic vision of where coal and power systems will be in 2015 and beyond. Vision 21 is a new approach to clean, efficient energy production from fossil fuels in the 21st century. It will integrate advanced concepts for high-efficiency power generation and pollution control into a new class of fuel-flexible facilities capable of producing electric power, process heat, and high-value fuels and chemicals with virtually no emission of air pollutants. In doing so, Vision 21 can create the opportunity for long-term, clean, and efficient use of fossil fuel resources to meet growing national energy demand while stabilizing greenhouse gas emissions.

The following *Strategic Plan* outlines how C&PS intends to continue the legacy of the CCT program successes in pursuit of Vision 21. Goals, objectives, and strategies for the C&PS program are provided. Additionally, program management and portfolio analyses are addressed and reflect stakeholder feedback on C&PS research and development (R&D) efforts. The chapters that follow the *Strategic Plan* are the C&PS individual *Program Plans*, which contain more detailed descriptions of individual program activities and milestones.



COAL & POWER SYSTEMS PROGRAM

Mission

The mission of the Coal and Power Systems R&D program is to foster the development and deployment of advanced, clean, affordable fossil-based power and alternative fuels systems. Fuel-flexible power generation and conversion technologies will be developed to efficiently utilize coal, natural gas, opportunity fuels, and other feedstocks. The long-term focus is on the effective utilization of coal — the Nation's most abundant energy resource — and natural gas. Government-sponsored research in partnership with industry, laboratories, and academic organizations will promote U.S. global leadership in coal fuels and power system technologies, creating U.S. jobs and contributing to a stronger economy.

Vision

Economically viable technologies will be available for clean production of low-cost electricity, and low-cost fuels from coal will raise global living standards for future generations.

As the leader in developing ultra-high-efficiency energy technologies with near-zero emissions, the United States will benefit from plentiful, low-cost electricity supplies and alternative fuel sources. The United States will produce a significant share of the products and services being used in the fast-growing world energy market, while enhancing its trade balance, and creating highly skilled, well-paying jobs.

ENERGY OUTLOOK

Fossil fuels are, and will continue to be, the primary source for power generation and fuel systems.

The DOE Energy Information Administration's (EIA) *Annual Energy Outlook 2000* projects that U.S. reliance on fossil fuels will rise from the present level of 85 percent to 90 percent by 2020 under current trends of price and usage. The EIA also projects that the use of fossil fuels to produce electricity will rise from the current 67 percent to 78 percent by 2020. Approximately 300 gigawatts of new electricity generating capacity is expected to be required by 2020. Of this, 50 percent will be gas-fired peaking units, and 40 percent will be gas combined-cycle. In addition to the EIA projections, the existing fleet of coal-based power plants is aging and much of it will be nearing retiremant by 2020.

By 2020, U.S. petroleum imports, already representing over 50 percent of consumption, are projected to rise to 65 percent and increase the U.S. negative balance of payments. Total worldwide petroleum demand will double, creating a very competitive market for increasing amounts of imports from sources that may be politically unstable. The challenge is to provide the technical basis for a clean fuels industry capable of producing transportation fuels from coal and other carbonaceous, non-petroleum, domestic resources.

Of greater interest though, is energy consumption in the developing world (Asia, Africa, the Middle East, and Central and South America),

which is expected to more than double by 2020, with the highest growth rates expected in developing Asia and Central and South America. In fact, energy use in the developing world is projected to surpass that of the industrialized world by 5 percent in 2020 — some 12 quadrillion Btu — whereas in 1997 energy consumption in the developing countries was about 40 percent lower than that in industrialized countries.

Opportunities abound for enhanced economic prosperity, with the challenge lying in providing the energy to sustain both economic and population growth while addressing global and regional environmental concerns, particularly carbon emissions. Fossil energy is the only means of fueling the tremendous

worldwide economic growth envisioned over the next two decades. As much of the world makes the transformation to industrialization, electricity represents an increasingly large part of the energy requirement. The worldwide demand for low-carbon-emitting technologies and cost-effective, safe carbon capture and disposal techniques will be enormous. The C&PS program is responding to these realities by introducing, and continuing to improve upon, a new generation of more efficient, affordable, and environmentally friendlier fossil fuel systems. With much of the developing world planning to use fossil fuels, particularly coal, the deployment of high-efficiency fossil systems is key in the approach to addressing global climate change concerns.



PLANNING ASSUMPTIONS

Planning assumptions, used to develop the strategy for the C&PS program research and development needs through the planning period 2000 to 2020, are summarized below.

Environmental Challenges with Fossil Fuels. Fossil fuel combustion, especially coal combustion, is likely to be subjected to increasingly stringent emissions limits. Pressure The need to reduce emissions of SO₂ and NO_x will come from several directions: the reduction in acid deposition; reductions in smog in major metropolitan areas; lowering ambient levels of fine particulate matter; and elimination of visibility impairment in 156 national parks and wilderness areas in the United States. Pressure to reduce emissions of mercury from coal-fired power plants is also likely. The emissions control requirements for the Organization for Economic Cooperation & Development countries are also expected to be more stringent.

Competition Among Fuels. In most instances, coal cannot compete economically or environmentally with natural gas as the fuel for new power plants in the U.S. under current price scenarios. This situation is likely to persist for the next few decades, primarily because advances in gas turbine technology (and other conversion technologies) will continue to favor gas, and deregulation of the generation portion of the electric system will likely make gas the preferred fuel for new sources and for repowering.

However, the cost of coal is likely to remain low and the cost of gas

may rise as demand for it increases. Also, coal power is projected to grow rapidly in some parts of the world, most notably in China and India, where indigenous non-coal fuels are scarce and expensive.

Global Energy Concerns. World carbon emissions are expected to reach 8.0 billion metric tons by 2010 and 9.8 billion metric tons by 2020. In developing countries, carbon emissions are projected to grow more quickly. Emissions from the developing countries were about 60 percent of those from the industrialized countries in 1990, but by 2010, developing countries will surpass industrialized countries with respect to carbon emissions. The sharp increase is expected to be caused both by rapid economic growth, accompanied by growing demand for energy, and by continued heavy reliance on coal, especially in developing Asia.

International concerns over the future impacts of greenhouse gases produced by anthropogenic activities have led to an international consensus that cost-effective measures to reduce the growth of greenhouse gas emissions are prudent. Some nations remain concerned about the uncertainties of potential longer-term impacts (2100 and beyond). Domestic and international sources are also pressing for large absolute reductions in the near term. Technologies being developed to allow the use of indigenous resources must address these concerns.

Electric Utility Restructuring. The uncertainties associated with utility restructuring have exacerbated concerns over the reliability

and quality of electric power delivery. Reserve margins are shrinking as energy suppliers increase capacity factors on existing plants, rather than install new capacity to meet growing demand. This increases the probability of forced outages and reduced power quality. Utility restructuring also shifts the burden of financing new energy ventures from the consumer to the power supplier. This favors less capital-intensive projects, and projects that can be permitted and constructed in the shortest possible time, including smaller, modular power systems for the distributed generation and combined heat and power markets.

Programmatic Challenges. Federal funding for fossil energy research will remain relatively constant. However, supporting the R&D necessary to achieve widespread deployment of new technologies with reduced investments from industry requires an expansion of public/private partnerships, a focusing of R&D efforts, and introduction of new approaches to mitigate development costs.



DRIVERS

- One-half of the world increase in energy use by 2020 will occur in Asia (primarily China and India). Energy use in developing countries that rely primarily on fossil fuels will surpass that of the industrial world by six percent.
- The global market for electric power systems is estimated to be as high as \$290 billion by 2030; as such, it will represent the most significant market for U.S.-produced power systems.
- By 2020, the electric utility industry will have been totally restructured; its markets will demand economic competitiveness and environmental performance.
- By 2020, nearly 70 percent of the petroleum used in the U.S. will be imported; as is the case today, most of this oil may still come from politically unstable countries.
- The regional and global environmental challenges of ozone, $PM_{2.5}$, global climate change, CO_2 , and hazardous air pollutants need cost-effective solutions if fossil fuels are to remain an economically viable energy source.
- Over time, the energy sector will be transformed, and in some instances, converge with other industry sectors to create a different energy landscape and interdependent industrial infrastructures in which fossil fuels will continue to dominate. Flexible, advanced technologies will be needed to address the needs of the new industries.
- Escalating demands for electricity coupled with an outdated power delivery grid pose a serious threat to the national economy.

GOALS

- Eliminate environmental issues as barriers to fossil fuel production and use, while maintaining the availability and affordability of fossil fuels.
- Ensure the availability of secure, affordable liquid fuels and reliable electricity.
- Provide scientific and technological information and analysis to assist policymakers and regulators in their decision making.
- Focus on public benefits-driven investment in high-risk, high-return technology that private companies alone cannot undertake.
- Create viable fossil energy technology options to address global climate change.
- Improve electricity grid reliability from a power generation standpoint.

OBJECTIVES

- Develop near-term, advanced, coal-based technologies to improve power generating capacity and grid reliability.
- By 2006, provide the capability to produce ultra-clean transportation fuels that will help vehicles meet U.S. EPA Tier II emissions standards.
- By 2015, provide the Nation with a sustainable supply of ultra-clean fuels produced from diversified feedstocks that meet all environmental requirements, are produced at economic costs, and meet performance requirements of advanced transportation systems.
- Between 2003 and 2008, provide technologies to improve the environmental performances of existing coal-fired power plants and reduce compliance costs by 25–75 percent, compared to existing technologies and strategies.
- By 2007, deploy commercially-scale, fully integrated coproduction plants that demonstrate the benefits of producing fuels, electricity, and other products from gasification technologies.
- By 2008, develop and deploy in initial markets key advanced power technologies including fuel cells, turbines, and enabling technology such as gas separation membranes.
- By 2015, make commercially available a new generation of advanced power, fossil fuel-based systems (e.g., Vision 21 Systems) that can use multiple feedstocks, coproduce multiple products, achieve near-zero emissions of traditional pollutants, nearly double the average fleet efficiency of today's power plants, and be compatible with carbon sequestration systems.
- By 2015, develop low-cost carbon sequestration technologies that can be integrated with advanced fossil fuel systems (e.g., Vision 21 systems) that will be commercially available in the same time frame.
- Remove barriers for U.S. companies in markets for clean, efficient fossil-fuel technologies in developing countries.

STRATEGIES

- Complete multiple demonstrations under the Power Plant Improvement Initiative.
- Produce ultra-clean fuels for testing, and develop advanced processes for production from feedstocks including crude oil, coal, natural gas, and biomass.
- Develop control technologies that will help ensure the ability to meet, at reasonable cost, planned or anticipated future regulation governing conversion of fossil fuels to electricity, clean fuels, and related products.
- Deploy one or more early entrance coproduction plants that demonstrate the feasibility of producing fuels, electricity and other coproducts from coal and other carbonaceous materials.
- Advance three-phase slurry reactor technology to cost-effectively produce premium fuels and other products.
- Complete the development of a suite of power systems, including pressurized fluidized-bed combustion, integrated gasification combined-cycle, indirect fired cycles, turbines, and combined cycles for application in central power generation.
- Advance the development of small generating units, focusing on fuel cell and fuel cell/turbine hybrids for distributed generation applications under 30 MWe.
- Integrate advanced power modules with other advanced fossil systems to achieve Vision 21 fleet of plants that can maximize economic, energy, and environmental efficiency.
- Develop low-cost technology options for CO₂ management that would include capture, separation, use, and disposal.
- Provide/exchange information relating to the development and deployment of clean and efficient energy systems.

PROGRAM EVALUATION AND ANALYSES

Changes in energy markets and Administration policies will affect R&D initiatives being pursued under the guidance of C&PS. As such, management of the C&PS Strategic Plan and supporting Program Plans is achieved through a number of different "checks and balances" on the current and projected R&D within C&PS.

C&PS conducts periodic reviews of its *Strategic Plan* to ensure that it remains dynamic and flexible to accommodate changing market behaviors, policy mandates, public perceptions, and other social science aspects of technology adoption. Development of solutions to knowledge and engineering gaps are achieved through a number of program evaluations as described below.

Portfolio Analysis

A number of studies have analyzed or reviewed all or parts of the C&PS portfolio of R&D. This section reports on the most relevant of those studies, including key conclusions and recommendations for future C&PS direction.

Federal Energy Research and Development for the Challenges of the Twenty-First Century (PCAST). This report, issued by the President's Committee of Advisors on Science and Technology in 1997, was a review of the current national energy R&D portfolio. The report had many findings and recommendations. Specific to C&PS, PCAST recommended strengthening the emphasis on energy efficiency and

advanced coal-power programs, carbon capture and sequestration, fuel cell technology, and the marketing of U.S. energy technology internationally.

Vision 21: Fossil Fuel Options for the Future. In response to a request from the Deputy Assistant Secretary for C&PS, the National Research Council formed a committee to review the goals of the Vision 21 concept and to recommend systems and approaches for moving from concept to reality. Some of the committee's key findings from the 2000 study include:

- Vision 21 should eventually move toward becoming a separate program within FE and the primary focus of the C&PS program. Currently, Vision 21 has components of R&D within each of the C&PS programs, but is not yet a stand-alone program;
- Vision 21 should be linked to other federal agencies and programs in and beyond DOE;
- DOE should work with industry to develop a commercial deployment program to facilitate the early commercialization of significantly improved technologies;
- Computer-based modeling and simulation are critical to identifying and designing Vision 21 plant configurations;
- High priority should be placed on the development of fuel cell technology for centralized power systems, high-temperature coatings and materials, oxygen separation technology, and carbon capture and sequestration technologies.

Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation (PCAST). This report was issued by PCAST in June 1999 to review the U.S. stake in international cooperation on energy innovation. A key conclusion is that world energy demand and use are tightly linked to the U.S. economic, environmental, and security interests. To capitalize on this realization, recommendations include an increased focus on international technology transfer of innovations for energy supply technologies such as fossil-fuel decarbonization and CO₂ sequestration, as well as energy end-use technologies such as combined heat and power applications.

Carbon Sequestration: State of the Science. This joint study between the Office of Science and FE was commissioned to identify key areas for R&D that could lead to an understanding of the potential for future use of carbon sequestration as a major tool for managing carbon emissions. Under the leadership of DOE, researchers from universities, industry, other government agencies, and DOE national laboratories were brought together to develop the technical basis for conceiving a science and technology roadmap. This effort formed the basis for the Carbon Sequestration program within C&PS.

Roadmapping

Technology roadmaps seek to identify the scientific and technological developments needed to achieve a specific technology goal (e.g., efficiency gains and/or environmental performance). The use of roadmaps by C&PS is designed to show how specific R&D activities can create the integrated technical capabilities needed to achieve strategic objectives.

C&PS directs its R&D to align with achieving the public benefits of energy research in concert with industry needs. Specifically, C&PS constructs its individual program technology roadmaps to complement industry's near- and long-term expectations for advanced energy systems research. Through review of the Electric Power Research Institute's Electricity Technology Roadmap and the Coal Utilization Research Council's technology roadmaps, C&PS is able to parallel its R&D to complement industry's needs and developments.

C&PS Portfolio Response

The contents of this *Strategic Plan* have been defined and are continually re-focused through an ongoing process of portfolio planning and analysis, and technology roadmapping activities. The following highlights some of the recent C&PS initiatives in response to C&PS program evaluations. They combine the scientific strengths of the C&PS program, the national laboratories, and industry to provide a strong base for achieving the efficiency and environmental goals set forth in this plan.

Ultra-Clean Transportation Fuels Initiative (UCTFI). The UCTFI, jointly led by DOE's Office of Fos-

sil Energy and the Office of Energy Efficiency and Renewable Energy, in conjunction with industry, was created to develop advanced technologies for the fuels-sensitive elements of engines and emissions control systems, and to improve the quality of fuels used in transportation by supporting the development and deployment of ultra-clean fuels. The Fuels program within C&PS supports this initiative by developing coal-derived fuels to provide stable, clean, and affordable energy supplies for transportation.

Solid State Energy Conversion Alliance (SECA). SECA is a national-level concept to achieve mass production of low-cost, technically superior ceramic fuel cell technology. The National Energy Technology Laboratory (NETL), in partnership with Pacific Northwest National Laboratory, is coordinating industry, university, and national laboratory activities to reach the ambitious goal of providing solid state fuel cell technology at a cost of less than \$400/kW for stationary applications, and less than \$200/kW for transportation applications. This

breakthrough will allow widespread penetration into stationary distributed generation power markets and ultimately, into central station power markets in Vision 21 plants.

Early Entrance Coproduction Plant (EECP). An EECP is a gasification-based coproduction plant that is capable of processing multiple feedstocks (coal, biomass, municipal waste, etc.) and producing some combination of electricity, heat, transportation fuels, or chemicals. The concept of producing a varied slate of products — the exact combination of which could be tailored for specific markets — is a departure from traditional energy facilities.

NETL recently selected three companies — Waste Management and Processors, Inc.; Dynegy Power Corporation; and Texaco Natural Gas, Inc. — to lead teams that will design an EECP. The research completed by the three companies feeds directly into C&PS technology programs and provides important insights into the ultimate Vision 21 facility.





COAL & POWER SYSTEMS

TECHNOLOGIES FOR THE NEW MILLENNIUM